§2. Electron Temperature Measurements Using High Energy Lasers in LHD YAG Thomson Scattering

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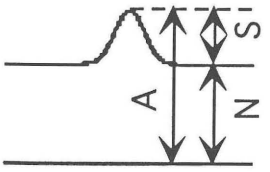
We have developed the LHD YAG Thmoson scattering (TS) [1][2]. In the LHD-TS, multibeam operations are possible by using several lasers [3]. We have four YAG lasers whose pulse energy is 0.5 J. When they are fired simultaneously, they work as a single 2 J laser. In the high-energy operation, the data quality can be expected to increase, especially for low density plasmas.

The data quality can be estimated as follows. In general, the true Thomson scattering signal, S, is obtained by suabtracting the background signal, N, from the measured signal, A, $S=A-N$.



The uncertainty δS is described as,

$$\delta S = \sqrt{\left(\frac{\partial S}{\partial A}\delta A\right)^2 + \left(\frac{\partial S}{\partial N}\delta N\right)^2}$$

$$= \sqrt{S + 2N}$$

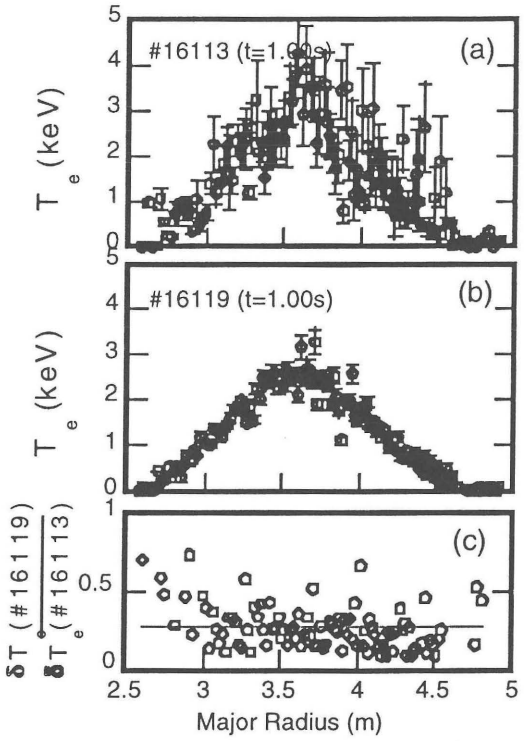
In this report, the data quality is defined as $S/\delta S$, and expressed in the two extreme cases,

$$\frac{S}{\delta S} = \sqrt{S} \quad \text{for} \quad N = 0$$

$$= \frac{1}{\sqrt{2}}\sqrt{N}\left(\frac{S}{N}\right) \quad \text{for} \quad \frac{S}{N} << 1.$$

Therefore, if the Thomson scattering signal is very weak, the data quality can be improved in proportion to a rise in S/N ratio, whereas it is proportional to $\sqrt{S}$ when the backgraound is negligibly small.

We show an example for such data quality improvement by increasing pulse energy. Fig.1 shows the comparison between the electron temperature profiles measured with single laser (a) and four lasers (b). The pulse energy of each laser is 0.5J. The four lasers are fired almost simultaneously (10 nsec interval). The two profiles were obtained under similar plasma conditions. Clearly, the data quality is improved in the high power mode for such low density plasma discharges. The ratios of the experimental uncertainties are also plotted in Fig.1 (c). In this example, the errors are reduced to about one-third to one-forth by increasing total pulse energy by four times, as expected.



In addition to the multibeam high energy operation using four lasers, we have made Thomson scattering measurements using single high energy YAG laser whose pulse energy is 2.5 J, and found that the data quality can be increased significantly. The degree of the data quality improvement is now quantitatively analyzed.

References

[1] Narihara, K., *et al.*, Fusion Eng. Design, Vol.34-35, 67 (1997).

[2] Narihara, K., *et al.*, Rev. Sci. Instrum., Vol.72, 1122 (2001).

[3] Yamada, I., *et al.*, Rev. Sci. Instrum., Vol.72, 1126 (2001).